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SPACING OF *SPELEOMANTES ITALICUS* (DUNN, 1923): APPLICATION OF A GEOGRAPHIC INFORMATION SYSTEM (G.I.S.)

(AMPHIBIA, PLETHODONTIDAE)

INTRODUCTION

Geographic Information System (G.I.S.) is defined as: «an organized set of hardwares, softwares and people purposed to the acquisition, management, analysis, and visualization of alphanumeric and graphic informations referred to a determinate territory» (Ballestra *et alii* 1996, translated from Italian). In practice G.I.S. allows to represent determinate kinds of informations (i.e. georeferred data falling within a class or a physical quantity, that are positioned in a determinate reference system, usually a Cartesian one, such as UTM or Gauss-Boaga), showing them in form of maps.

Geographic Information Systems allow to carry out spatial analysis and manage large amounts of data with sustainable time and costs and are employed mainly in technological webs management, urban and territorial planning, and natural sciences (geobotany, faunistic, ecology, etc.) (cf. Ballestra *et alii* 1996), but so far G.I.S. have been used in herpetology only in few cases (Vigato *et alii* 2001; Carafa & Biondi 2002).

This paper reports the results obtained from the first applica-

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tion of G.I.S. in the study of Italian cave salamander *Speleomantes italicus* (Dunn, 1923) spacing strategies.

MATERIALS AND METHODS

The study site is a natural cave called «Grotta del Tritone», 43°53'52" N - 11°58'06" E, near Bagno di Romagna, (province of Forlì-Cesena, Italy), already described by PASTORELLI *et alii* 2002a. The *Speleomantes italicus* population gravitating around the cave is object of a long-term study in order to investigate several natural history traits, such as population structure, seasonal activity, habitat use and displacement, and behaviour (PASTORELLI *et alii* 2001, 2002a and 2002b; LAGHI *et alii* 2005).

The site was visited monthly from January 1999 to December 2000 and during each sample session salamanders were searched for by two persons inside and outside the cave (close to the entrance) for about an hour. For each salamander captured, sex, body length (from the snout tip to the anterior end of the vent), distance from the entrance and from the cave floor were recorded. Adult salamanders were sexed by means of the observation of exterior secondary sexual characters -i.e. the presence, in the adult males, of a mental body gland (LANZA 1959) and enlarged premaxillary teeth- and all individuals reaching a wider body length than the smallest male possessing a mental body gland (41 mm) were considered as adults; as in *Speleomantes* females reach sexual maturity at a larger size than males (SALVIDIO 1993), in this study some large subadults were likely considered as adult females.

Salamanders were photographed to allow individual recognition by means of comparison of the dorsal patterns (SALVIDIO *et alii* 1994; LAGHI *et alii* 2005) and at the end of each session were released at their capture site.

A virtual map, integrated in a Cartesian reference system in real scale, with co-ordinates in meters, was obtained from the longitudinal section of the cave, with the aid of softwares ArcView GIS version 3.1 and Topol 4.0 (see figs. 1-3 and fig. 4, above). Another virtual space (see fig. 4, below), representing on the same plane the cave floor and walls, was created to allow a reliable calculation of home range size. For the sake of ease, in this latter space cave floor was assumed to be 2 m wide along the whole extension of the cavity; actually floor width range from 0.4 to 3.2 m, 2 m being the average value in the first 25 meters from the entrance.

Data about spacing of *S. italicus* were integrated in both virtual spaces by software ArcView GIS version 3.1, then processed by software Animal Movement for Spatial Analyst 2.04 Beta, by means of kernel (95% and 50%) method, a nonparametric statistical method for estimating probability densities from a set of points. The resulting graphs provide immediate visualization of the probability of find animals in any one space, by means of a colour scale (RODGERS & CARR 2002).

Calculation of home range shape and size, by means of the Minimum Convex Polygon (MCP) model, were also provided by Animal Movement for Spatial Analyst 2.04 Beta.

RESULTS AND DISCUSSION

During the study period 440 records on the spacing of *S. italicus* were collected (236 in the year 1999 and 204 in the year 2000). Some data, which were not included in calculations in the study by PASTORELLI *et alii* (2002a), have been herein taked into account, therefore sample size is larger than that reported in the previous paper.

Spatial distribution of salamanders was statistically different between the two years (Student t = -2.437, df = 438, P = 0.015), thus data obtained in different years were separately processed.

The number of active salamanders observed in the study site (mainly on cave walls and floor, rarely under stones or in clefts, both inside and outside the cave) was related to distance from the entrance, in function of sex (two records, referring to unsexed specimens, were excluded from calculations) and season. In all cases G.I.S. produced graphs that allow a quick and easy reading of the phenomena described by statistical analysis.

Cave salamanders were found at a mean distance from the entrance of 6.2 ± 4.4 m (n = 236) and 7.2 ± 4.6 m (n = 204) in the year 1999 and 2000 respectively. In both years only few salamanders (n = 3 in 1999; n = 2 in 2000) were observed outside the cave close to the entrance, and no captures were made inside the cave beyond 25 meters from the entrance (fig. 1) confirming previous studies (CIMMARUTA *et alii* 1999: *S. strinatii* and *S. a. ambrosii*; MORISI 1981 and SALVIDIO *et alii* 1994: *S. strinatii*; PASTORELLI *et alii* 2001 and 2002a: *S. italicus*).

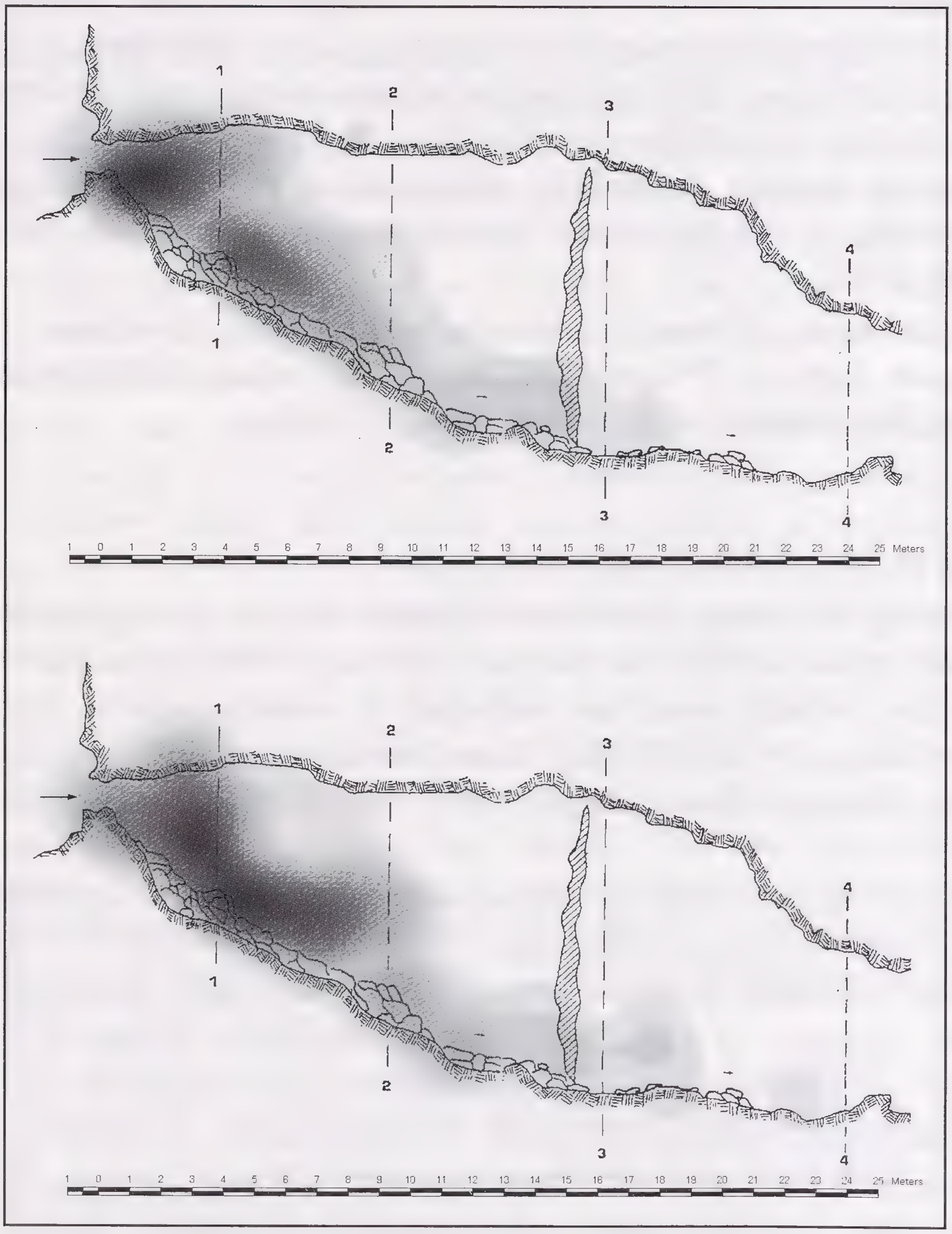
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Fig. 1 - Distribution of captures in the year 1999 (above) and 2000 (below). The colour becomes darker as the estimated probability of salamander presence increases. 1-1, 2-2, 3-3, and 4-4 indicate where transversal sections (showed in the original drawing) were taken.

Juveniles were found on average more close to cave entrance (3.8 ± 2.8 m, n = 110 in 1999; 4.2 ± 2.7 m, n = 93 in 2000) than adults (8.3 ± 4.4 m, n = 125 in 1999; 9.8 ± 4.4 m, n = 110 in 2000) (fig. 2). These data suggest that also in *S. italicus* a spatial segregation between juvenile and adult salamanders, such as that assessed by SALVIDIO & PASTORINO (2002) in *S. strinatii*, may occur (cf. also PASTORELLI *et alii* 2002a). No meaningful differences were found between spatial distributions of males and females in 1999, 2000 and both years added (Student *t*, P > 0.05 in all cases), although males were often found at an higher distance from the entrance than females.

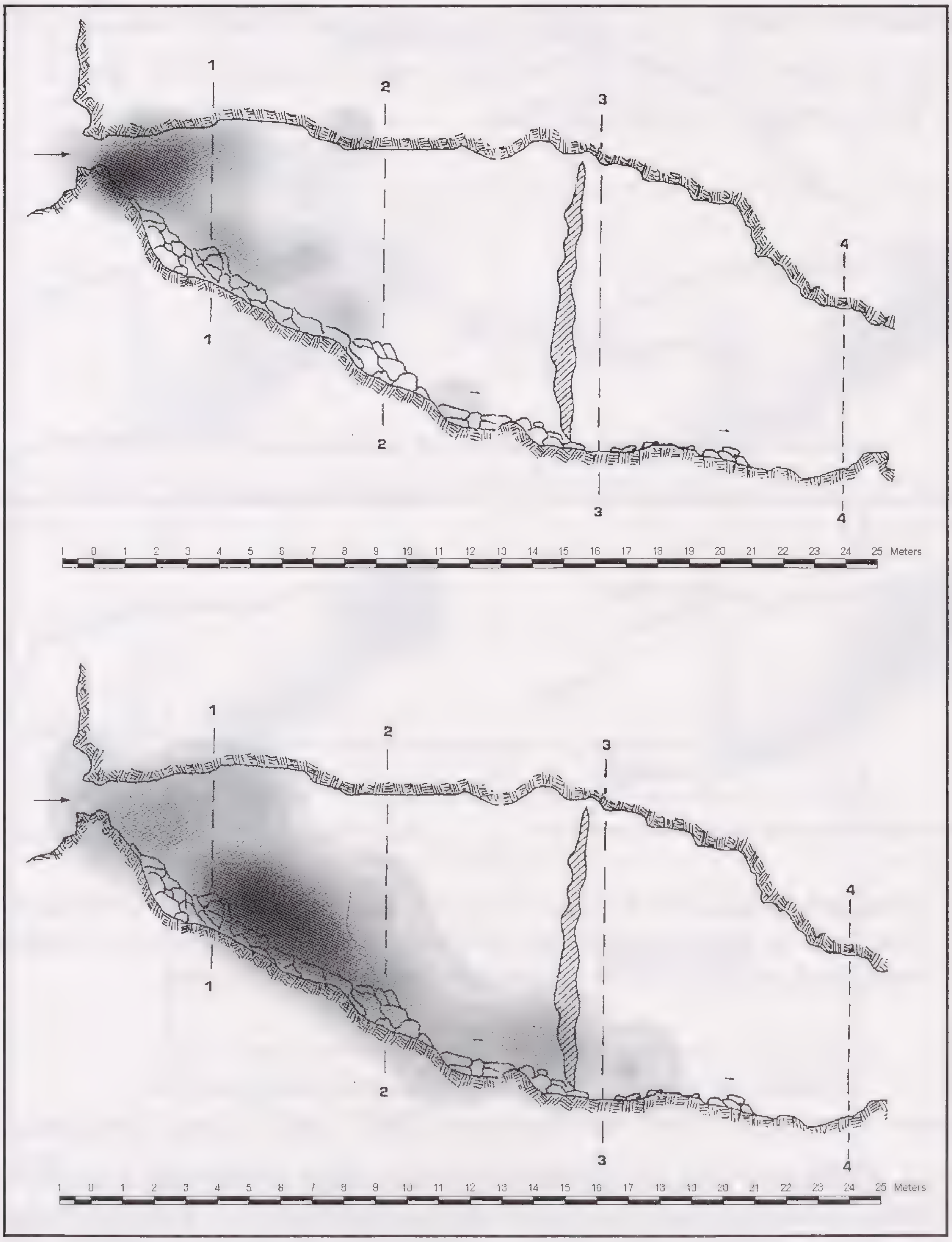
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Fig. 2 - Spatial segregation between juvenile (above) and adult (below) *S. italicus* in the year 1999. The colour becomes darker as the estimated probability of salamander presence increases.

In summer, when external conditions are prohibitive, cave salamanders are usually found at higher distance from the entrance than in spring and autumn (Pastorelli *et alii* 2002a: *S. italicus*; Salvidio *et alii* 1994: *S. strinatii*; Voesenek *et alii* 1987: *S. supramontis*). Fig. 3 shows that a similar seasonal spacing pattern occurred in the studied population in the year 1999. In summer months the animals were observed at a higher mean distance from the entrance (7.3 ± 4.4 m, n = 45) than in spring (5.5 ± 4.2 m, n = 96), and in autumn (7.0 ± 3.8 m, n = 71); in winter, when external environmental parameters were very similar to internal ones, cave salamanders were active close to cave entrance, even outside (4.3 ± 5.2 m, n = 24) (cf. Pastorelli *et alii* 2002a).

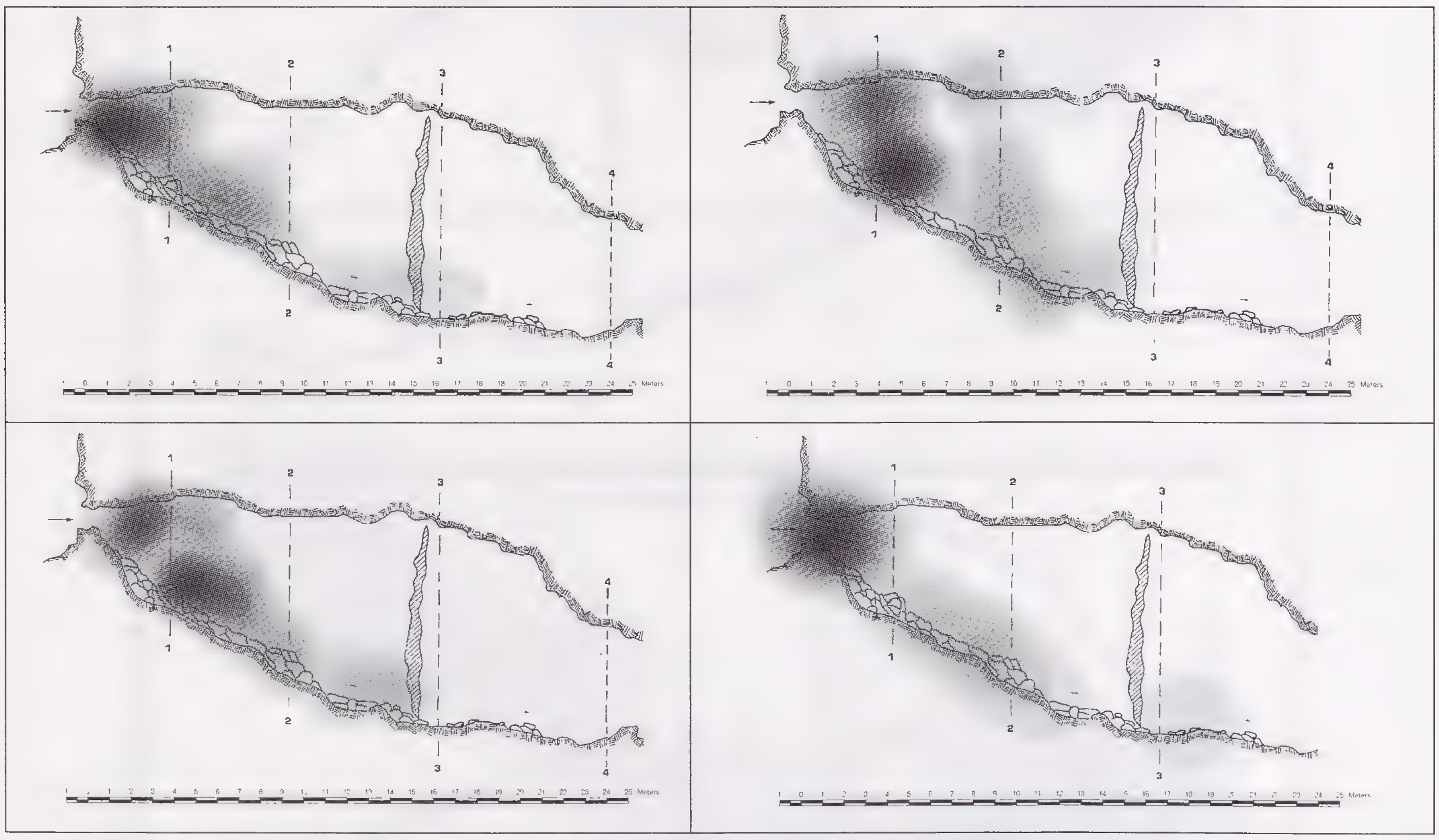
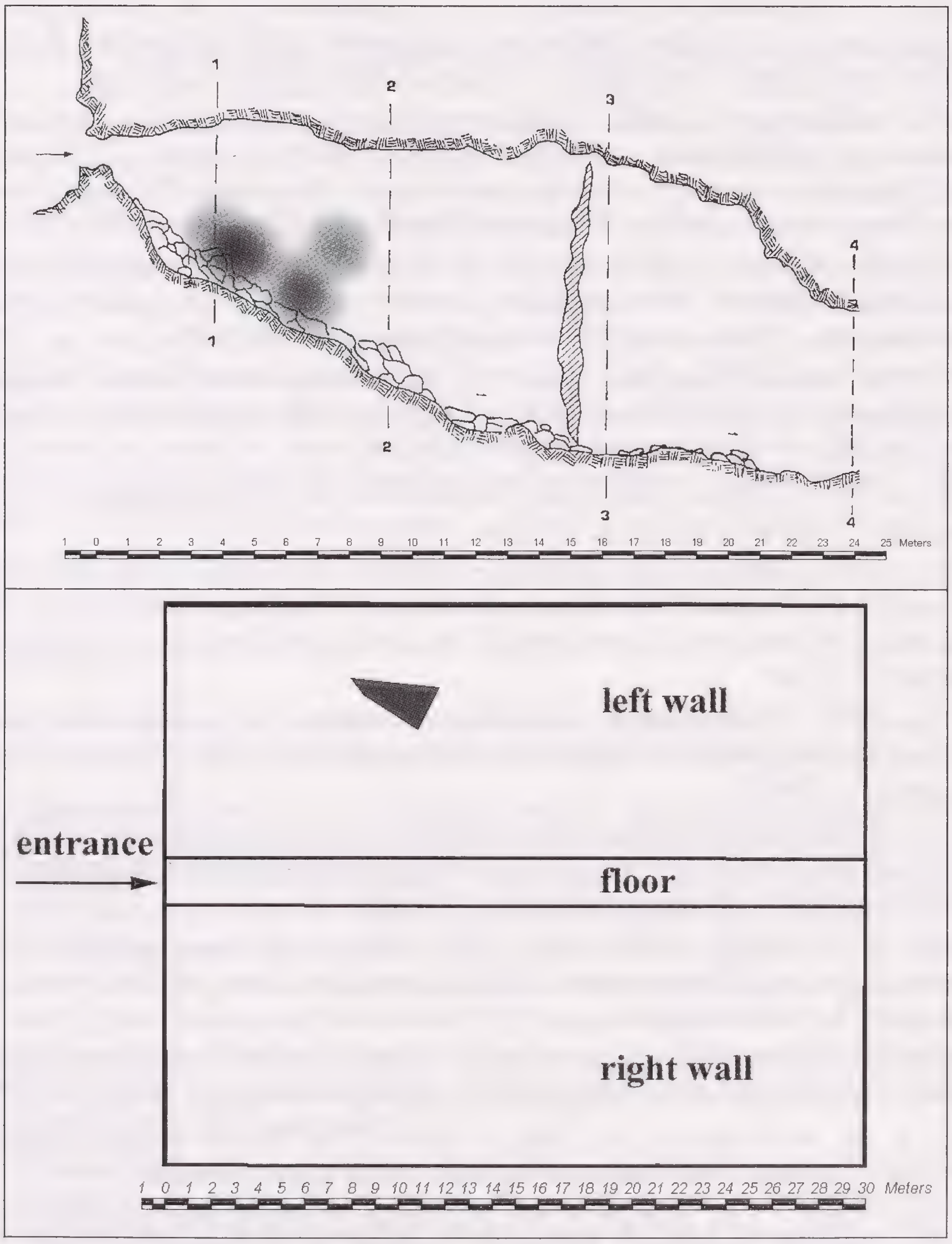


Fig. 3 - Seasonal spacing of *S. italicus* in the year 1999; clockwise from the upper left: spring, summer, winter, and fall. The colour becomes darker as the estimated probability of salamander presence increases

From January 1999 to August 2000 individual recognition by means of photographs of dorsal pattern was obtained for 215 specimens (108 immatures, 52 males and 55 females). Home range size, calculated only for 11 individuals captured at least 4 times, averaged 21.75 ± 25.24 m^2 (range = 1.75-82.26 m^2). It goes without saying that the observed home range represents only a part of the actual one, this latter being larger, as it extends also in rock interstices. Fig. 4 shows the home range of specimen n. 71, a female captured six times from May 1999 to July 2000. Data support LANZA's (1986) statement that cave salamanders possess much more vagility than is usually understood.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left wall
entrance
floor
right wall
1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 Meters

Fig. 4 - Home range of the specimen n. 71 (MCP size: 3.93 m^2). Above: kernel graph on the longitudinal section of the cave (the colour becomes darker as the estimated probability of salamander presence increases); below: MCP graph on the virtual space representing on the same plane cave walls and floor.

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ABSTRACT

For two consecutive years *Speleomantes italicus* spacing were studied with the aid of a Geographic Information System (G.I.S.), in a natural cave in northern Apennines. Individual displacement and spacing patterns with regard to sex classes and season were analyzed. The salamanders are found only the first tract (up to 25 meters from the entrance) of the cave, which is the area providing contemporarily plenty of food and steady environmental conditions. There were no differences between male and female spatial distributions. Most immature specimens were observed close to cave entrance, while adults were active mainly in deeper zones.

The occurrence of a spatial segregation between juveniles and adult cave salamanders has already been assessed in *S. strinatii* and it is likely to occur also in *S. italicus*. Spacing patterns were strongly seasonal, with the highest mean distance from entrance recorded in summer, and the lowest one in winter. Home range size, estimated for 11 specimens captured at least four times, ranged from 1.75 to 82.26 m^2 (mean = 21.75 m^2).

RIASSUNTO

Uso dello spazio in *Speleomantes italicus* (Dunn, 1923): applicazione di un Sistema Geografico Informatizzato (G.I.S.) (Amphibia, Plethodontidae).

Per due anni consecutivi l'uso dello spazio di *Speleomantes italicus* è stato studiato, con l'aiuto di un Sistema Geografico Informatizzato (G.I.S.), in una cavità naturale dell'Appennino Settentrionale. Sono stati analizzati gli spostamenti individuali e le variazioni nell'uso dello spazio in funzione della stagione e del sesso. Gli animali frequentano esclusivamente il primo tratto (fino a 25 m dall'entrata) della cavità, ossia il settore che fornisce sia abbondante cibo sia condizioni ambientali stabili. Non sono state riscontrate differenze significative tra le distribuzioni spaziali dei maschi e delle femmine. La maggior parte degli individui immaturi sono stati osservati nelle vicinanze dell'ingresso della cavità, mentre gli adulti frequentano principalmente zone più profonde.

L'esistenza di una segregazione spaziale tra geotritoni giovani ed adulti è già stata verificata in *S. strinatii* ed è verosimile anche per *S. italicus.* La distribuzione spaziale dei geotritoni è fortemente condizionata dal ciclo stagionale, con la massima distanza media dall'ingresso registrata nei mesi estivi e la minima in inverno. La dimensione dello spazio vitale, stimata per 11 individui catturati almeno quattro volte, varia tra 1.75 e 82.26 m^2 (media = 21.75 m^2).